DESTRUCTIVE EXAMINATION METHODS FOR THE INVESTIGATION OF NORTH ANNA HEAD PENETRATION #54

Presentation to

NRC Research

Rockville, MD

January 18, 2006

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Work Funded by Electric Power Research Institute (EPRI)

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Objectives

- Destructive Examination of Complete Alloy 600/82/182 Penetration/Weld from Service
- Physical Characterization and Identification of Head Penetration Weld Defects
- Identify Interrelationship between Various Types (Axial, Circ or Other) of Defects
- Characterization of Annulus Environment & Wastage
- Identify Mechanistic Aspects of Formation and Root Cause of Cracking

  (Leading to Correlation of Discovered Defects with Prior Reported NDE Indications)

Summary of Tasks

Preliminary NDE
Development of Sectioning Plan – Identification
Preliminary Sectioning
Additional NDE
Detailed Sectioning and Macroetch
Detailed NDE on Azimuthal Sections
Metallography
Chemistry
Hardness
Fractography
Fabrication History Review
Review of Results Assessments and Conclusions

Project Status

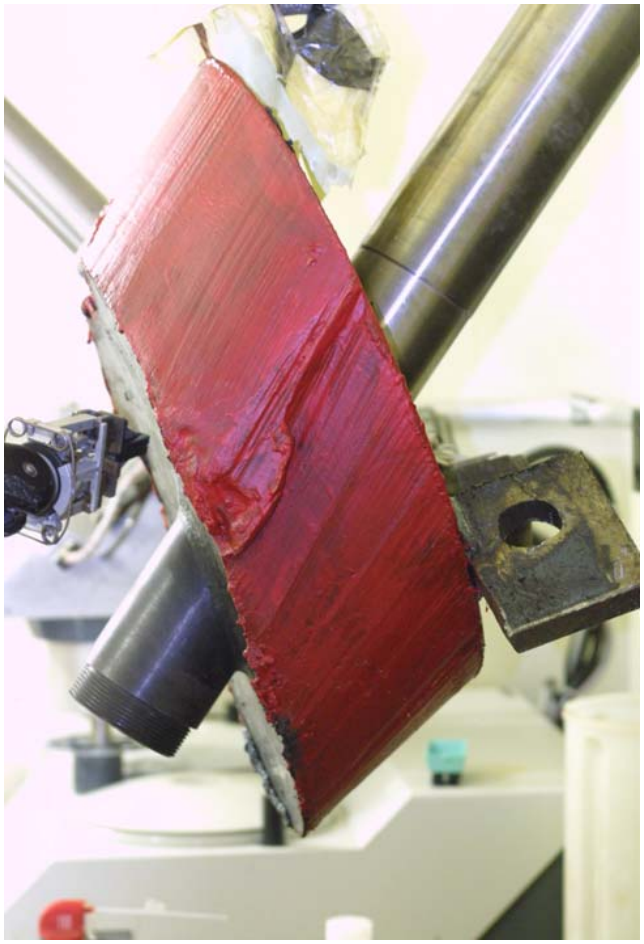
- Workscope 95% Completed
- Draft Report Initiated
- Final Report Scheduled for April 1, 2006

Presentation Focus

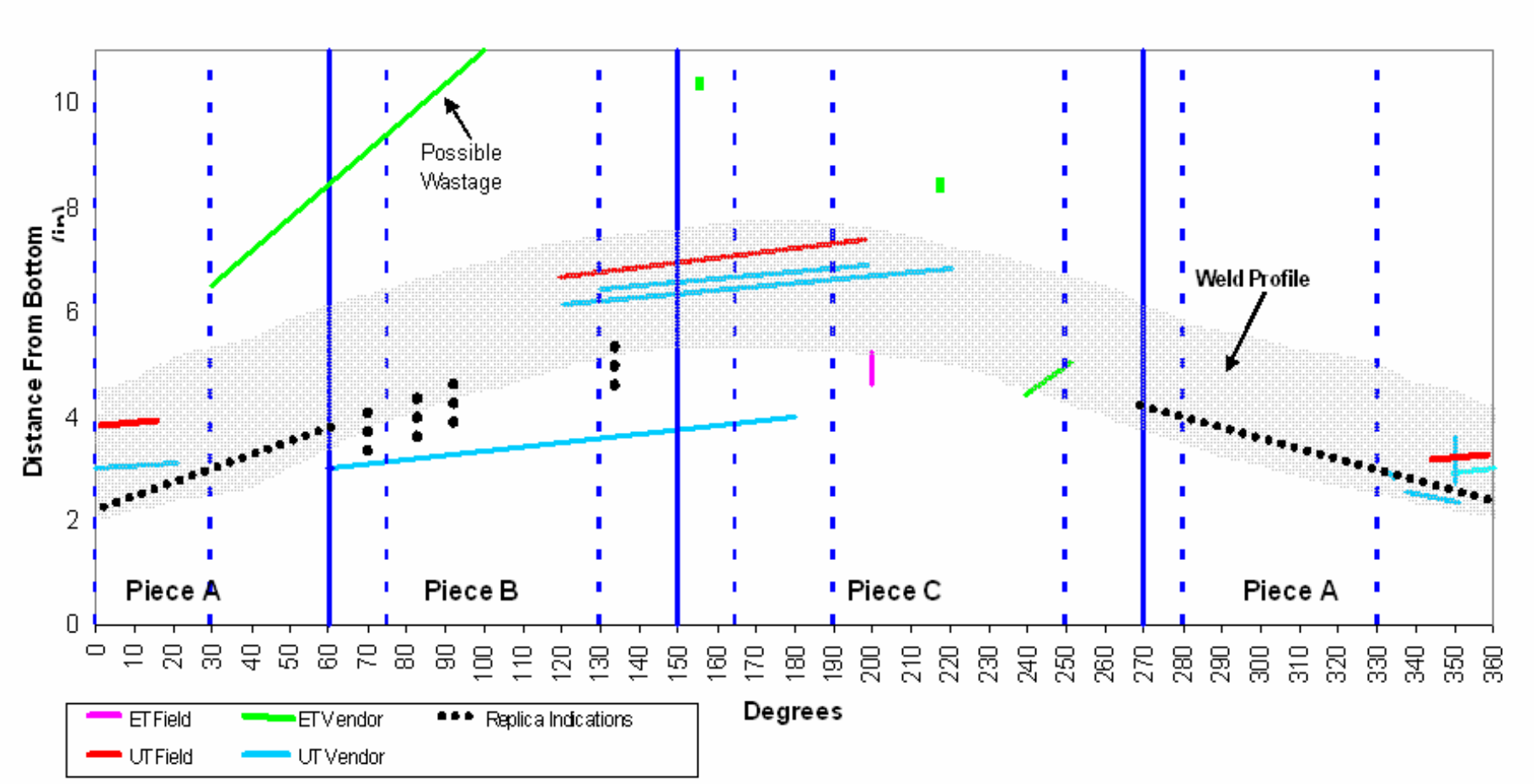
The Current Presentation is Focused on Two Aspects of the Destructive Examination

- Effective Utilization of Additional NDE Technologies
- Development of Innovative Sectioning Plan and Sectioning Methods
  - To Maximize Defect Characterization Capabilities
  - To Minimize Man-Rem Exposure

As-Received Condition of CRDM Nozzle 54



Vendor Inspection Data (Provided)



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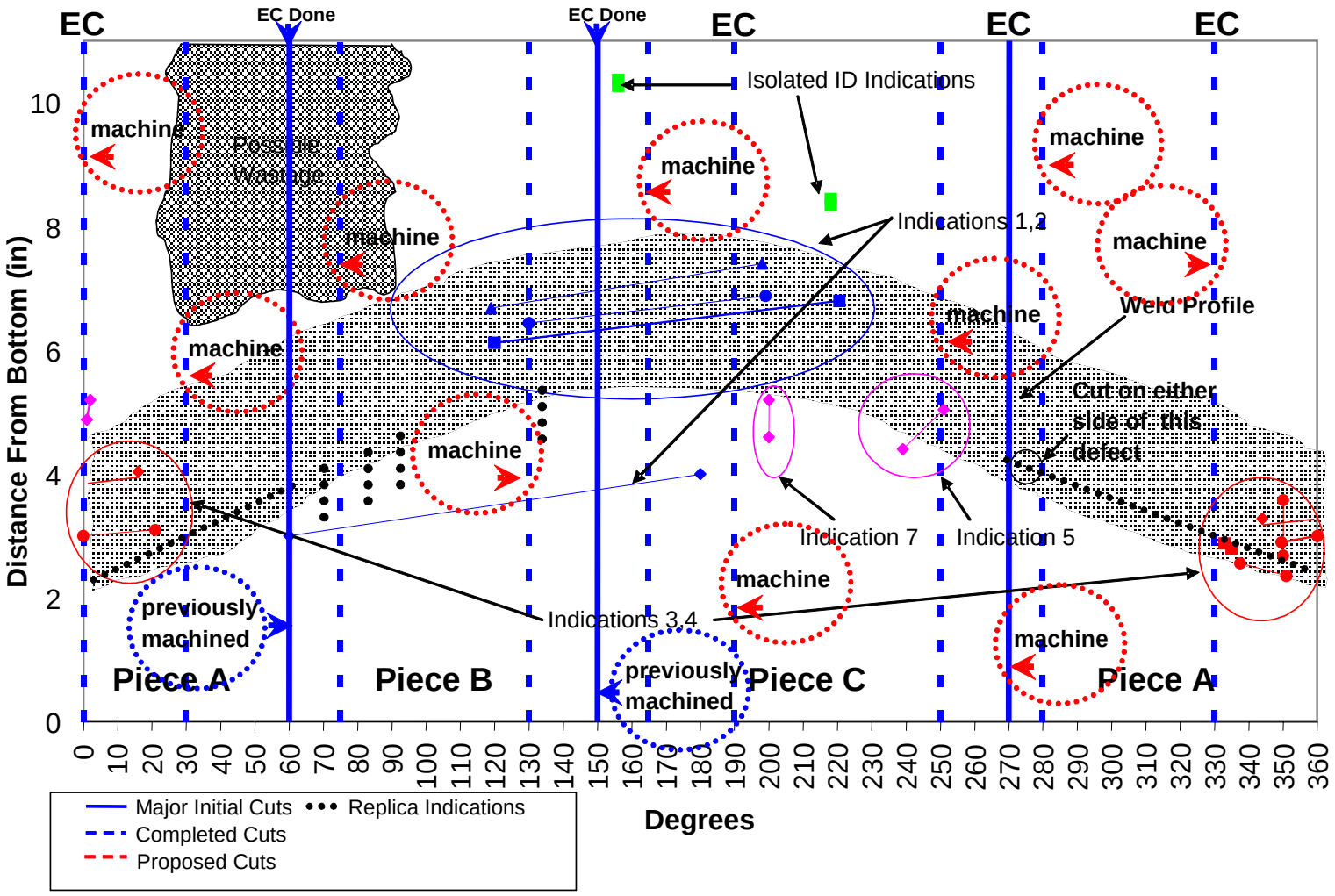
Vendor Inspection Data (Provided)



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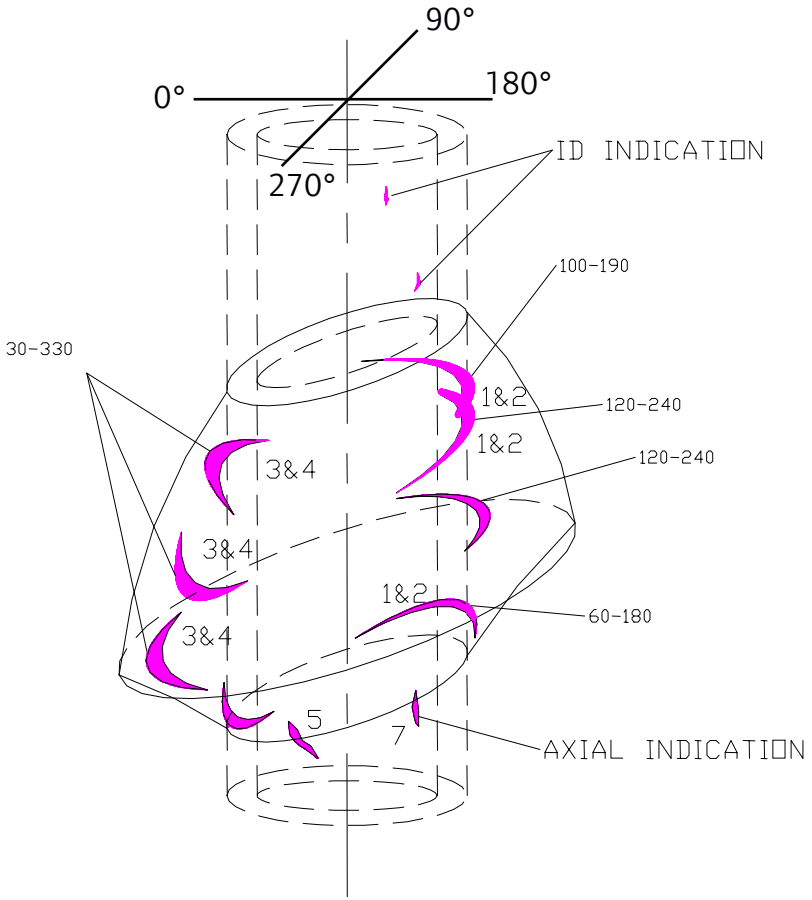
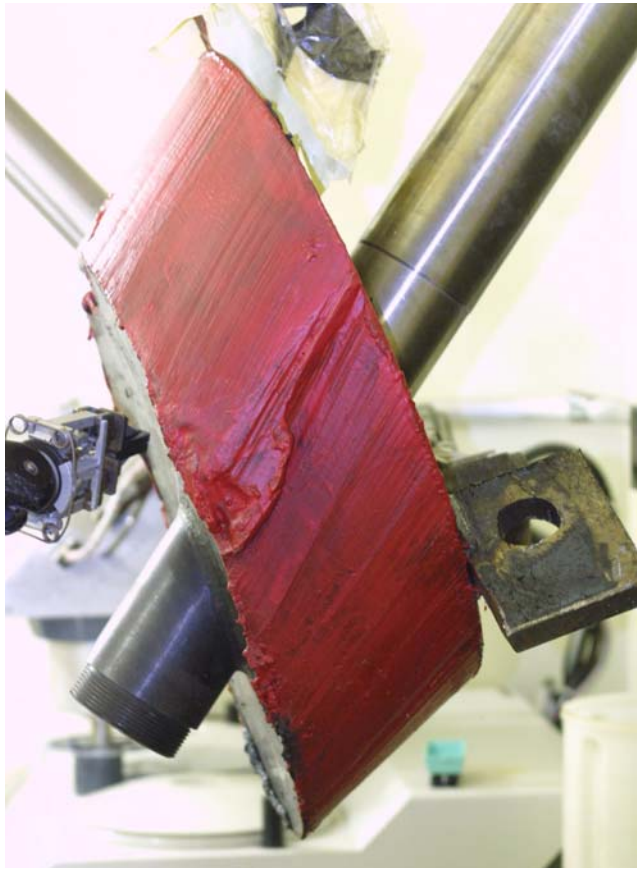
3-D Model of Indications Developed by Westinghouse To Guide Sectioning





- Developed a 3-D Model of Penetration Indications
- Compared Model to Physical Cut Out to Identify Best Sectioning Plan

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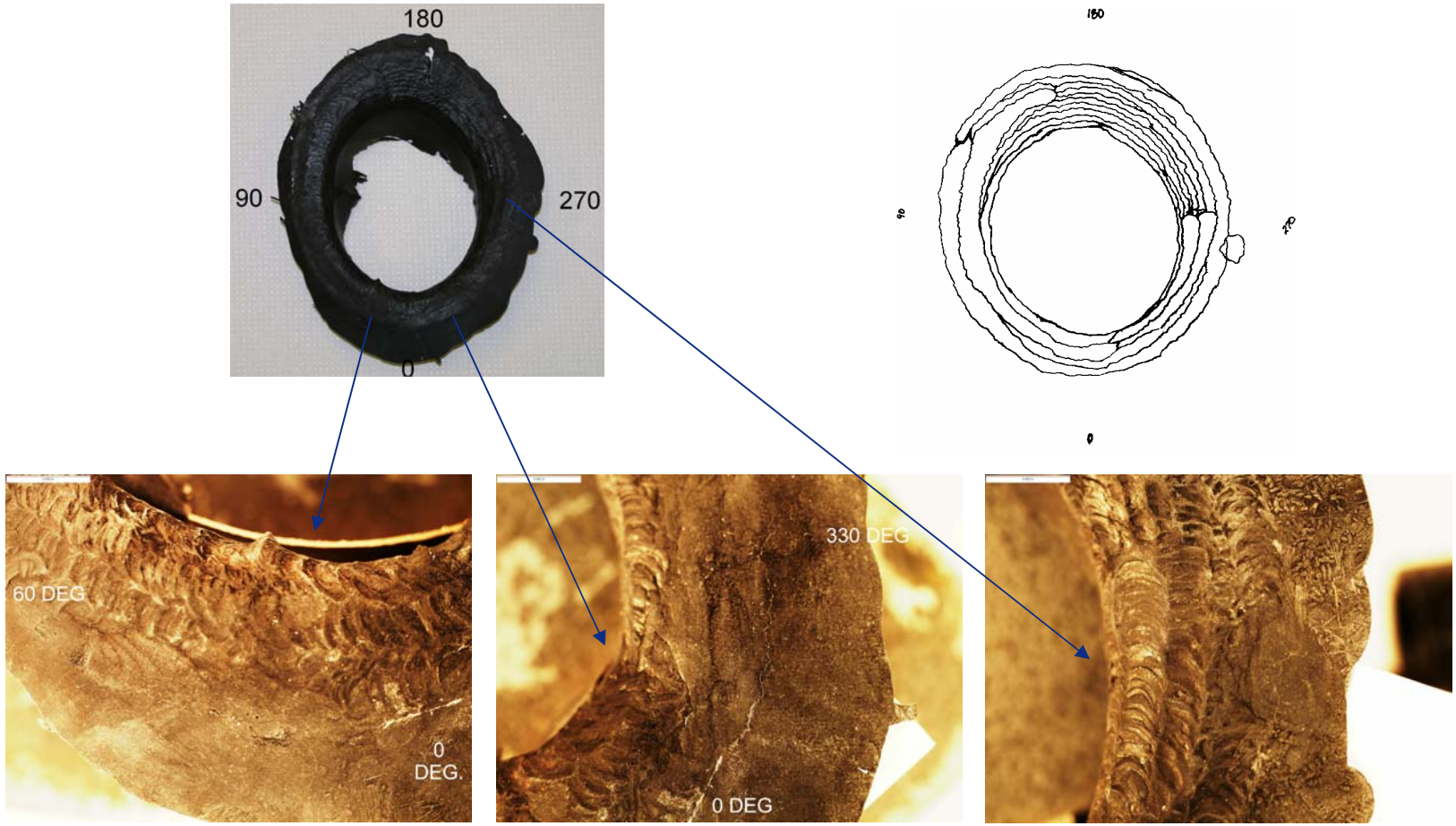
NDE Assessments – For Sub-Surface/Surface Emergent Crack Identification

- Microset (High Resolution) Replication
- Eddy Current Testing
- Florescent Dye Penetrant Testing
- Ultrasonic Testing

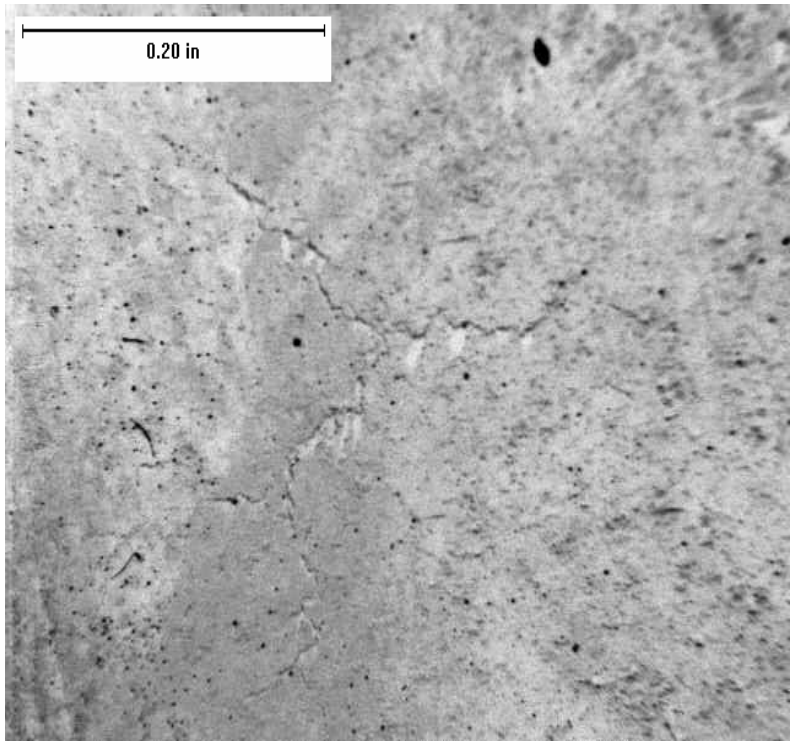
Replication to Preserve Data from Wetted ID Face Weld

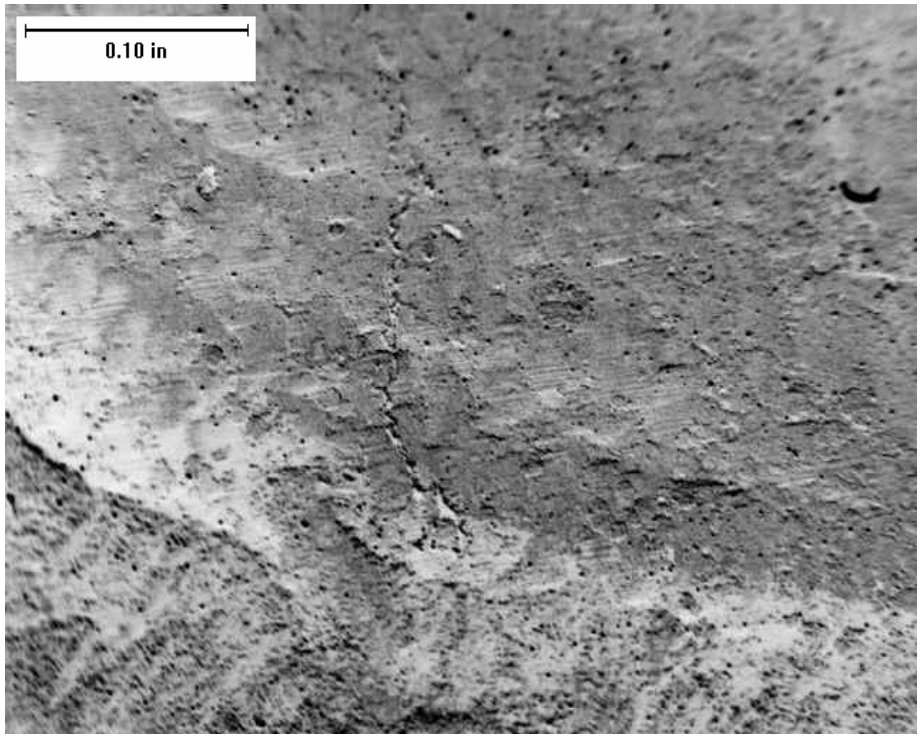
Wetted ID Weld Surface Replication



Allows Identification of Crack Emergence on J-Weld Wetted ID Face and Observation of Weld Bead Interactions

Specific J-Weld Indication via Replication

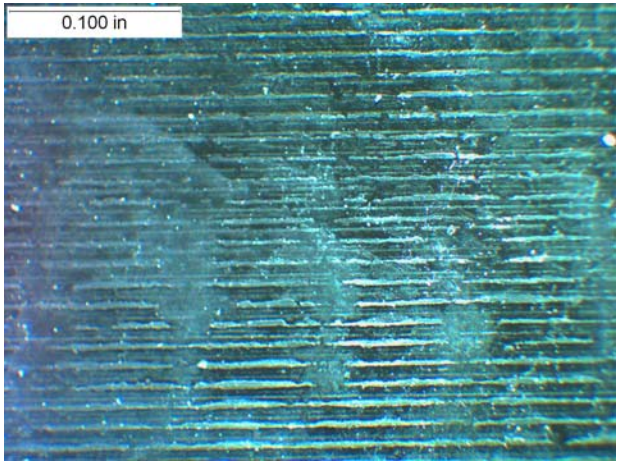




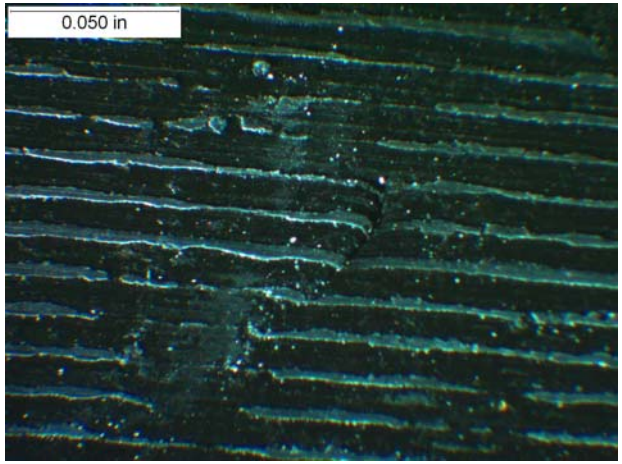
Replication Allowed Identification of Several Wetted Face Emergent Cracks – this one at 300° Location

Penetration ID Surface Replication

ID Replica Across
J-weld Region



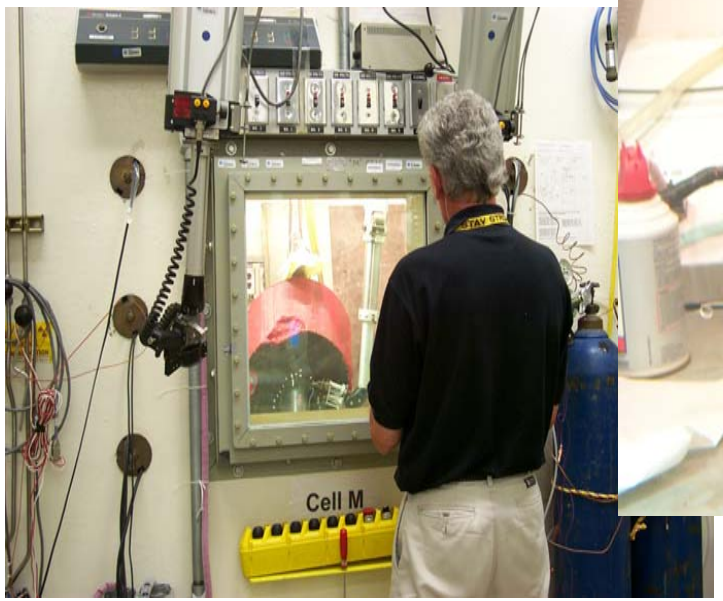
ID Scratch

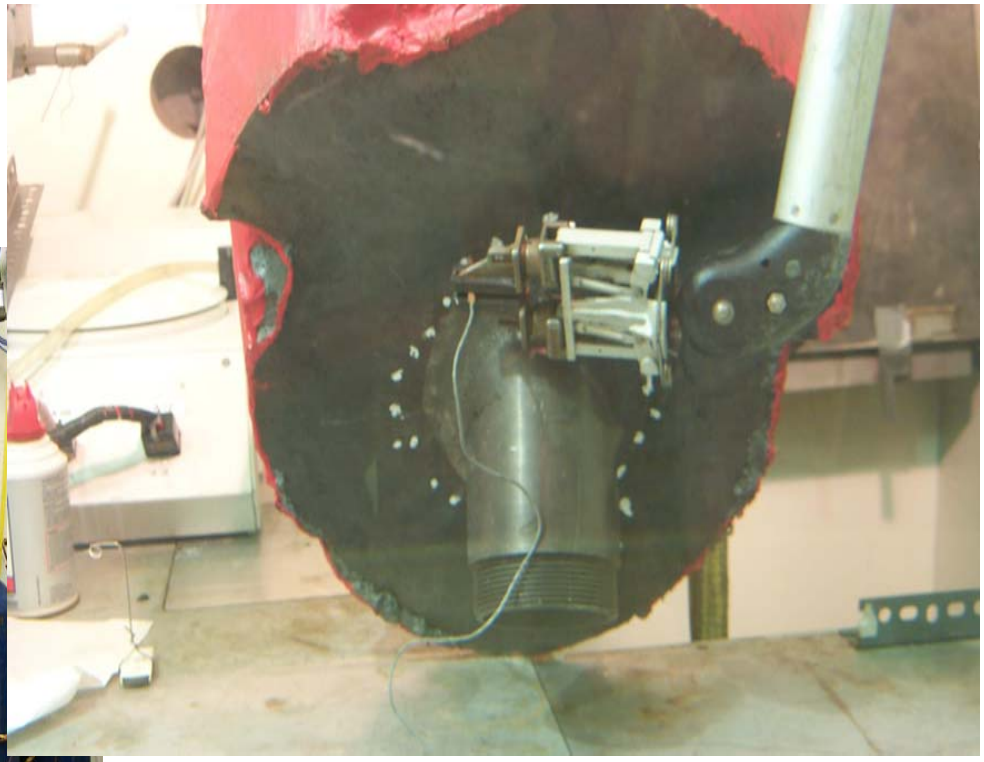


Surface Scratch

EC Pencil Probe Tracing of Weld Interface

To Confirm Profile of Weld Interface (Establishes Removable Excess Carbon Steel)





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Sectioning Layout to Remove Excess Carbon Steel (3 Inch Clearance from Weld)

Rough Cutting of NA Penetration 54

- Band Saw was Used with Appropriate Capacity (Modified Jet, 7x12" Horizontal/Vertical Band Saw). Recommend Use of Larger Saw.
- A 3/4 in Bimetal 5/8 in Variable Pitch Blade (Blade was Changed Frequently, Especially when Cutting Through Weldment). Speed, Feed and Pitch of Blade were Dependant on Horsepower of Drive Motor and Rigidity of Fixturing.

Removal of Excess Carbon Steel

- Fixture Capable of Rotational, Elevation and Lateral Adjustment
- Sample Holding Fixture Clamped to Saw Base to Assure Rigidity Between Sample and Saw Blade
- Top of CRDM Penetration Clamped to Fixture and Aligned with Blade
- Ratchet Cargo Straps were used to Maintain Position and Rigidity During Cut

Piece in Fixture for Removal of Excess Carbon Steel

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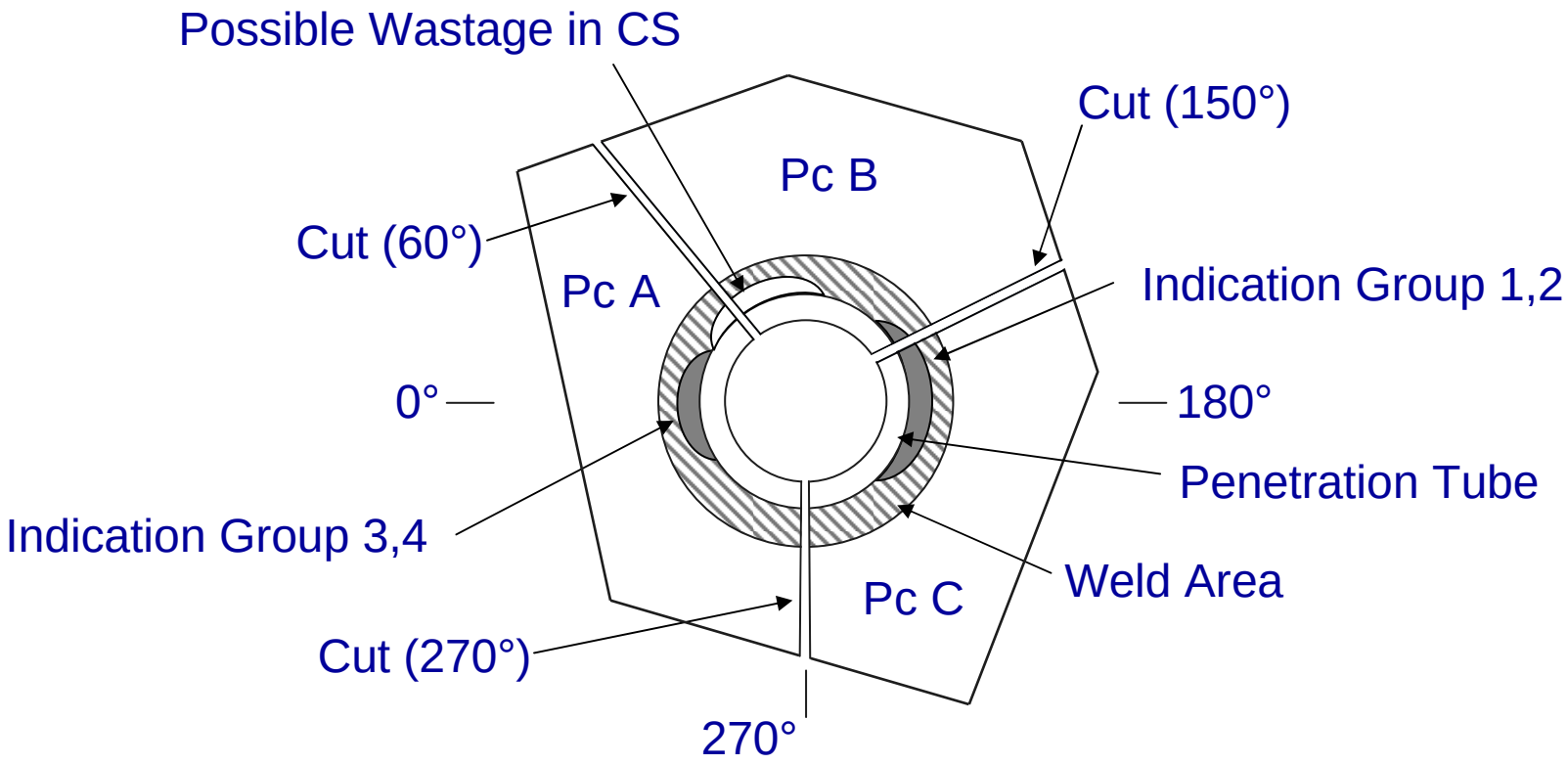
Initial Sectioning Plan



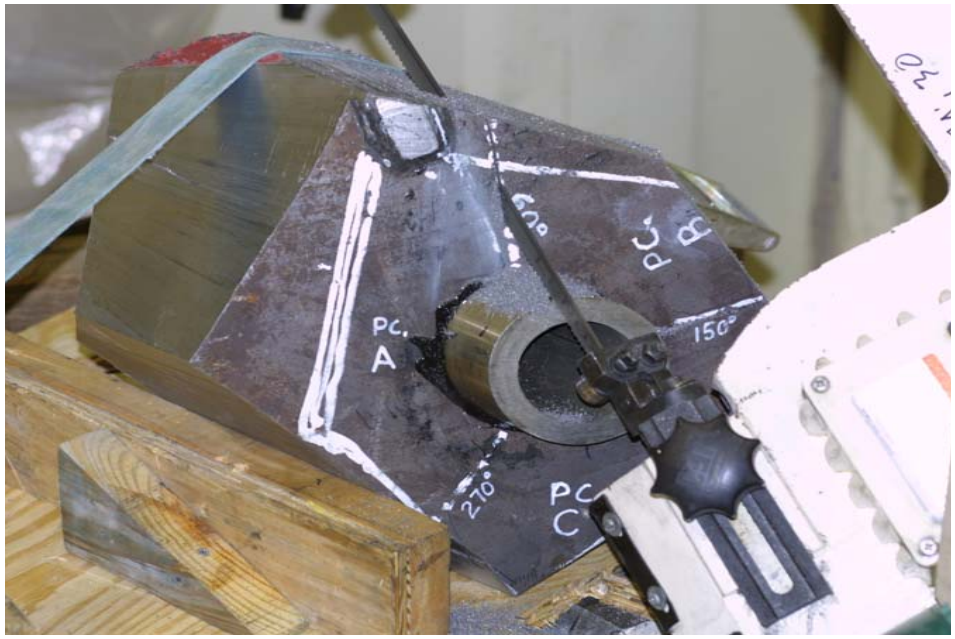
As-Sectioned Pieces A, B & C

Further Rough Cutting of NA Penetration 54

- Major Sectioning Conducted to Obtain "Pie" Sections:
  - Multiple vises used to align sample with blade.
  - Cargo straps and wooden spacers and/or machining "toe" clamps were used if support was required.
- Thinner Slices Were Cut off of the Major Pie Sections to Isolate Areas of Interest
- Additional Machining Done to Sliced Faces:
  - Multiple tilt machine vises and/or "toe" clamps were used to hold piece as it was being milled.

Sectioning Through Weld and Penetration

- Large Plywood Base Plate was Used to Support Sample
- Various Shape and Thickness Wooden Spacers were Used to Align Sample with Blade
- Ratchet Cargo Straps were Used to Maintain Position and Rigidity During Cut

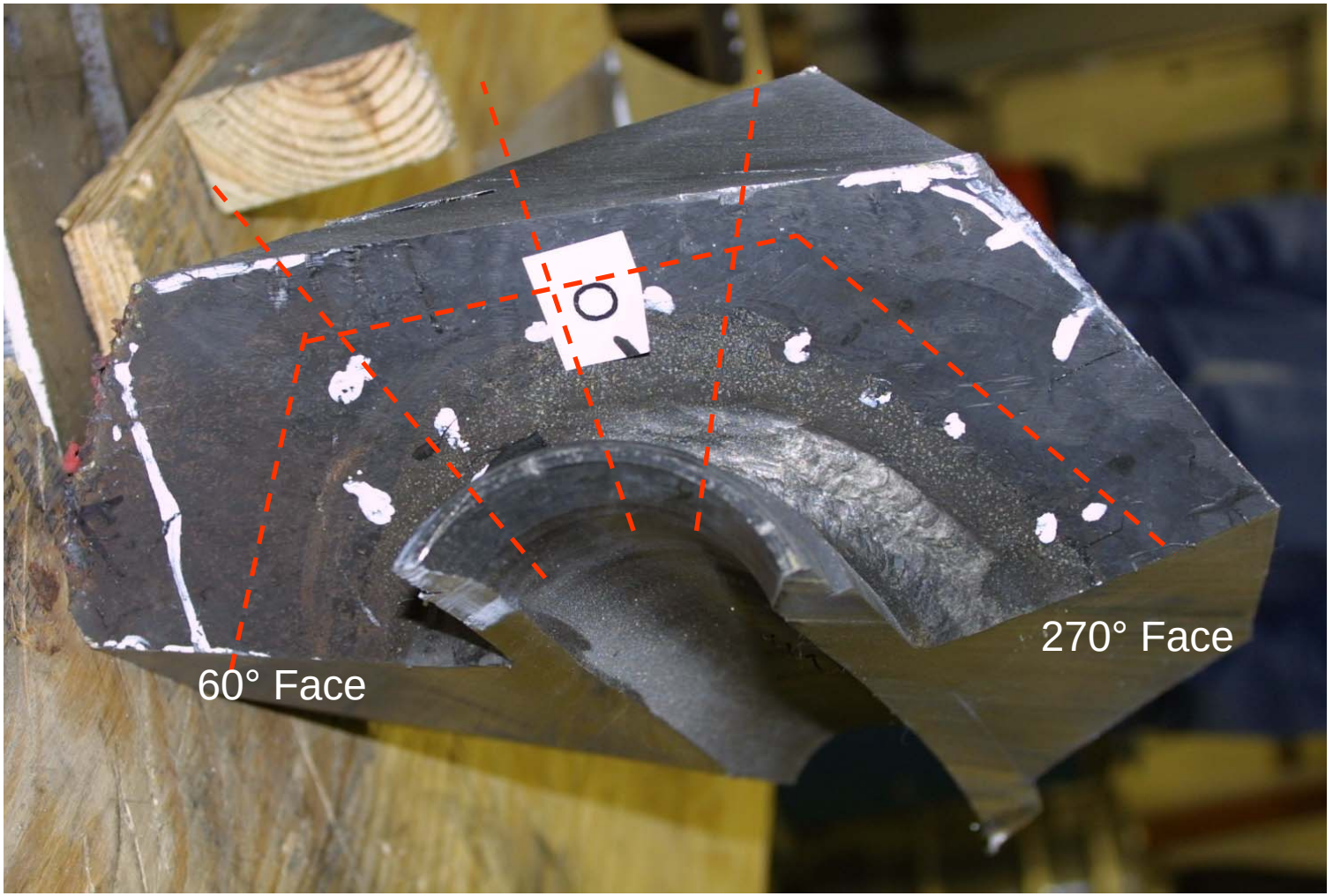


60° Cut

Sectioning Through Weld and Penetration

270 Degree Cut

Piece A



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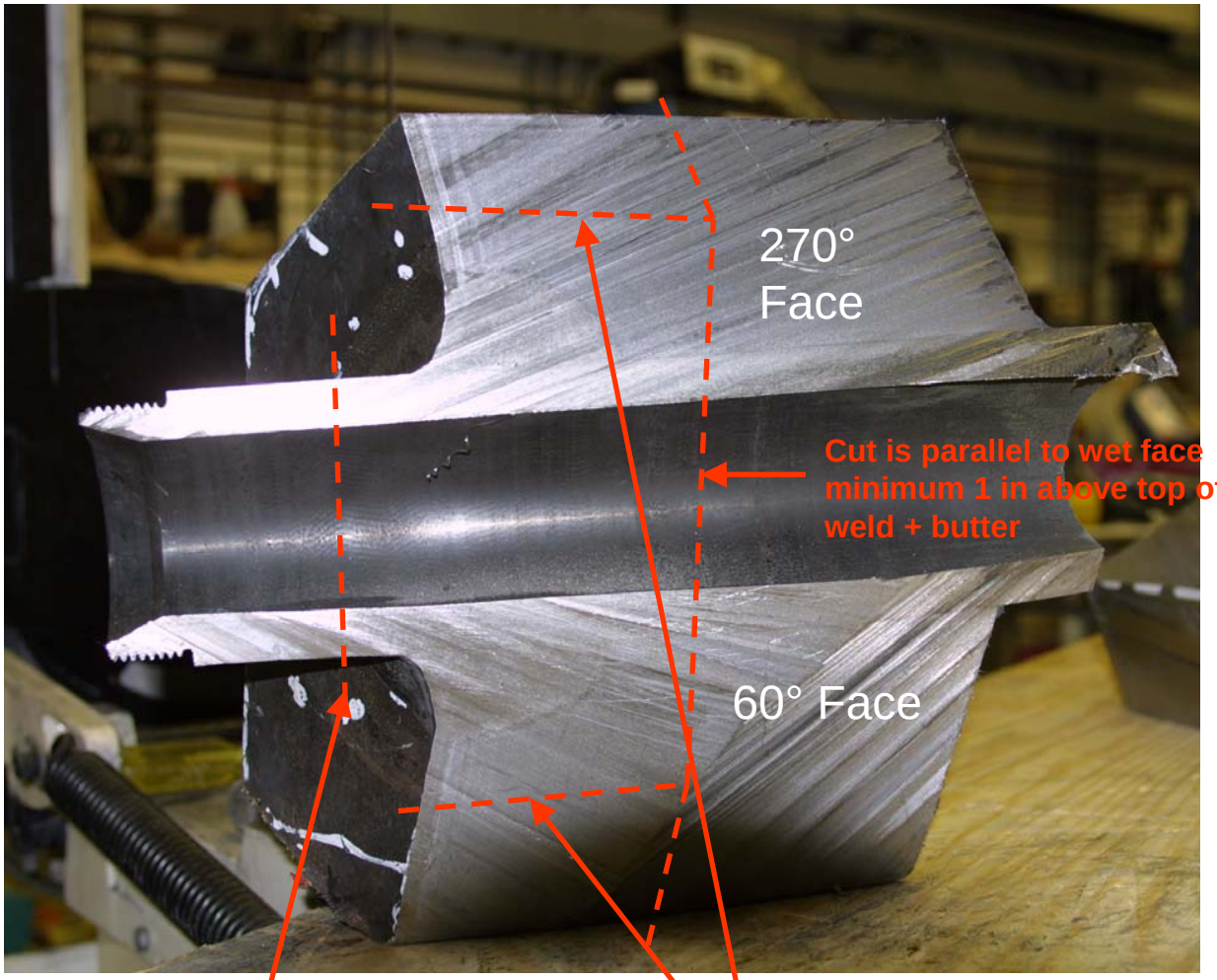
Piece A



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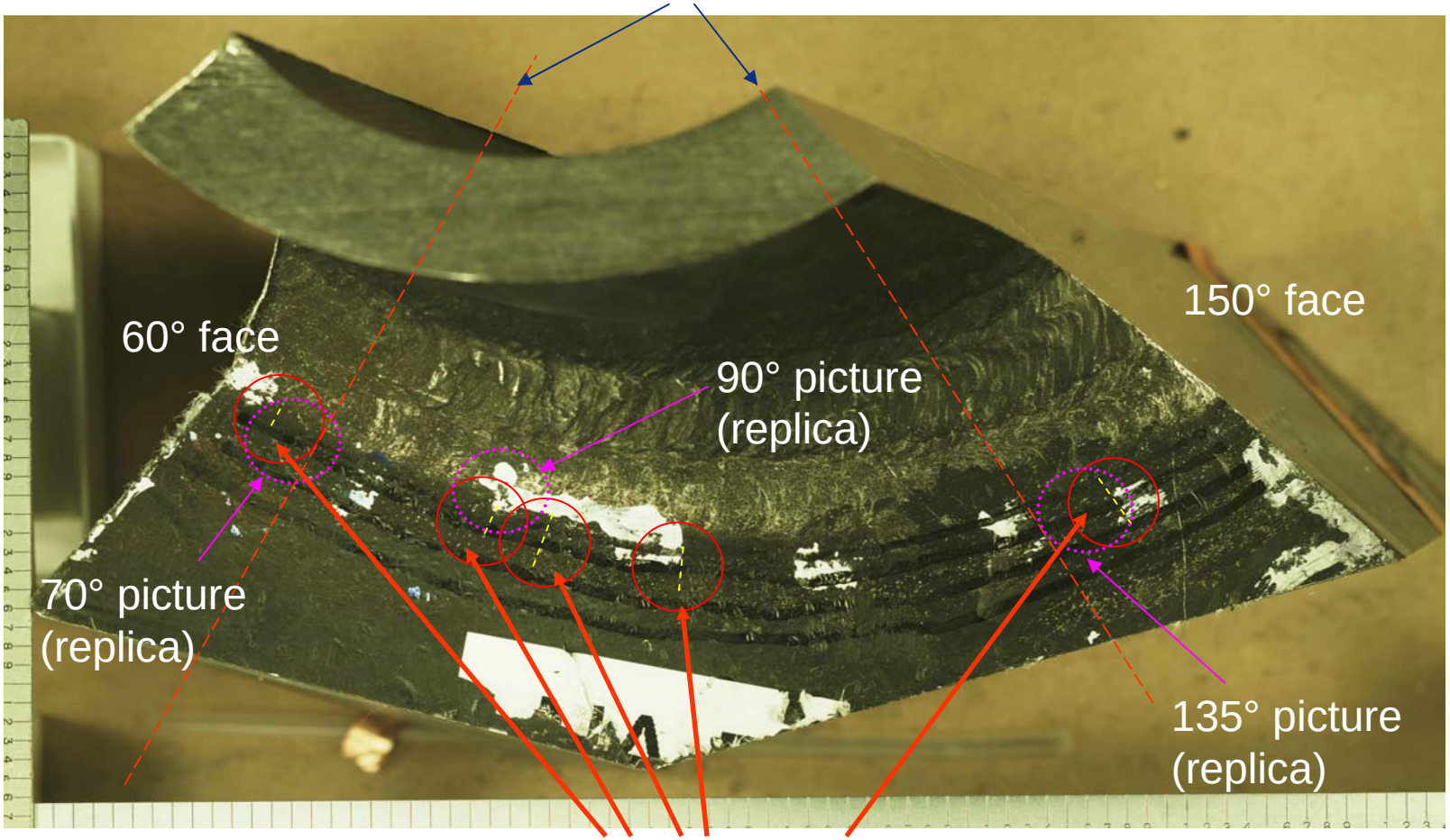
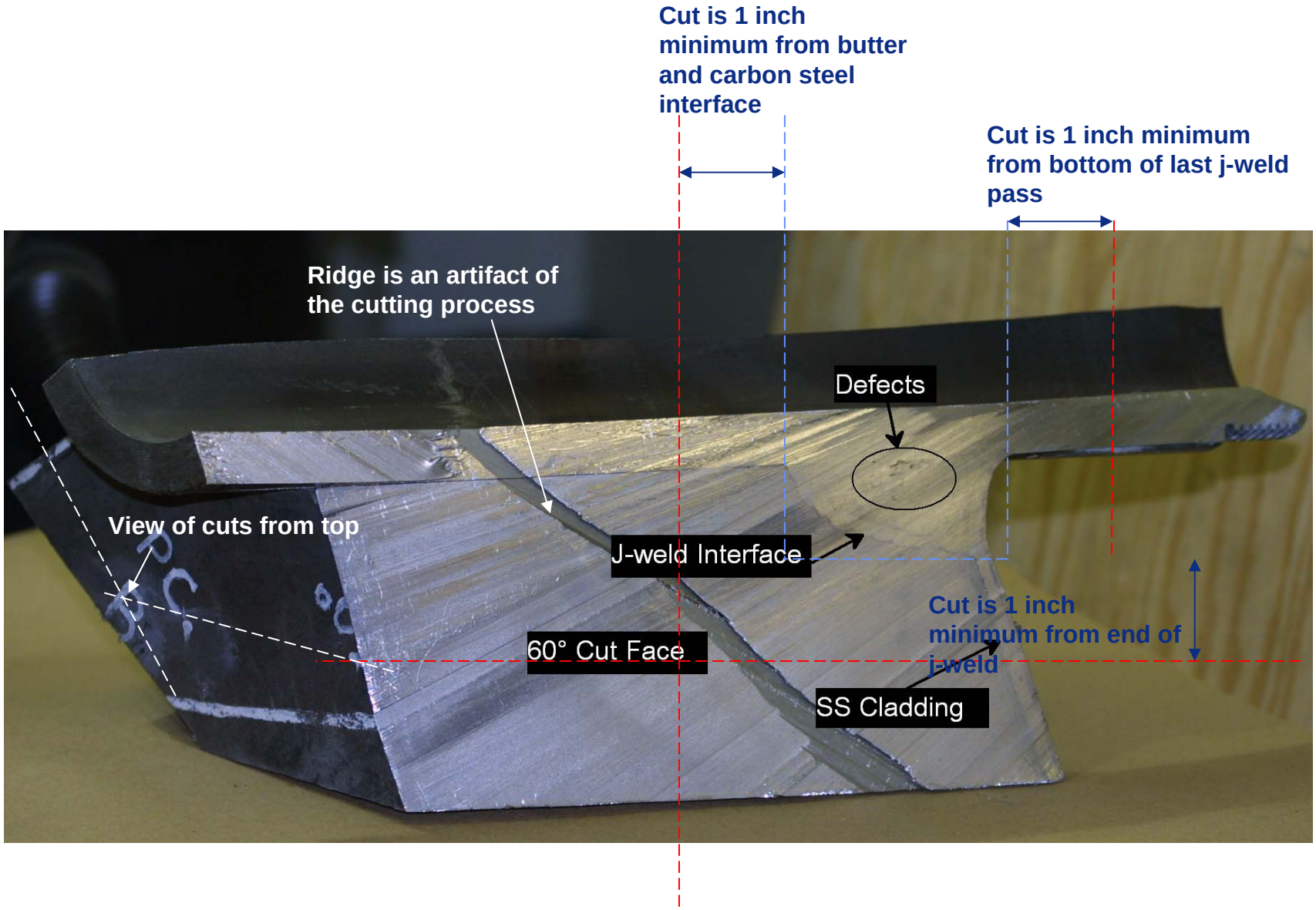
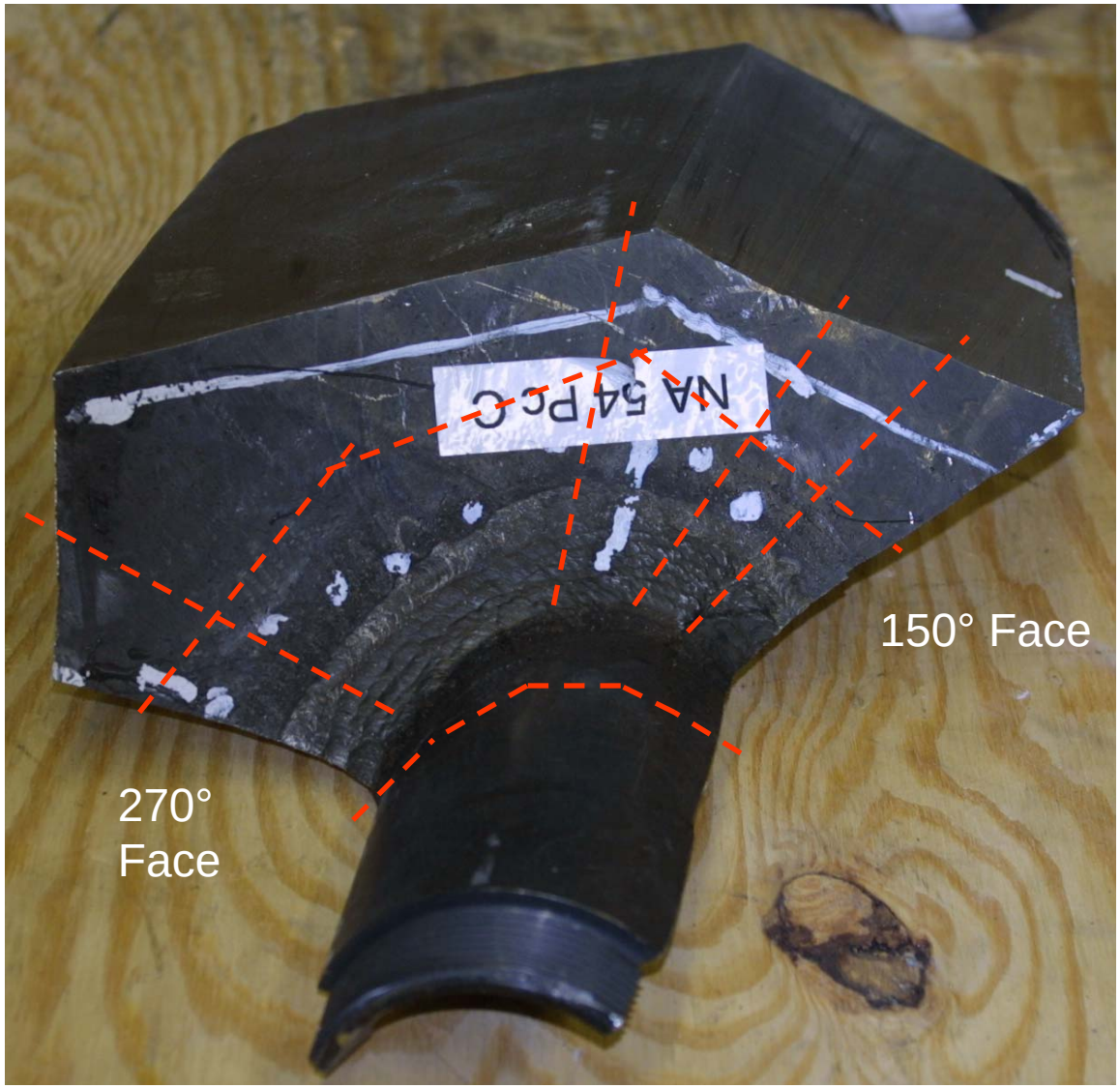
Piece B



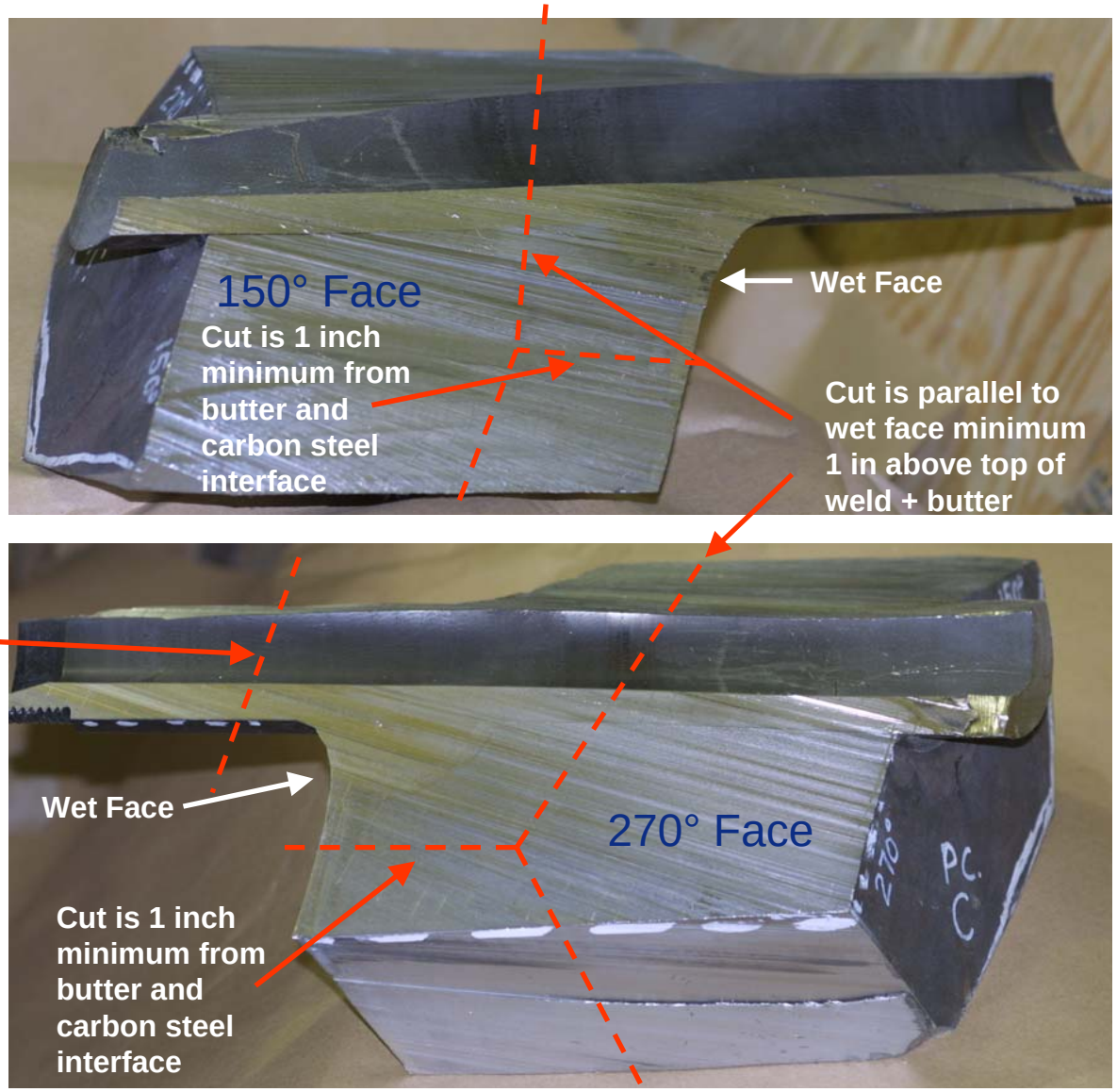
NDE Indications from NDE performed at W


Cut is 1 inch minimum from butter and carbon steel interface
Cut is 1 inch minimum from bottom of last j-weld pass
Ridge is an artifact of the cutting process
Defects
View of cuts from top
J-weld Interface
Cut is 1 inch minimum from end of j-weld
60° Cut Face
SS Cladding

Piece C



Piece C



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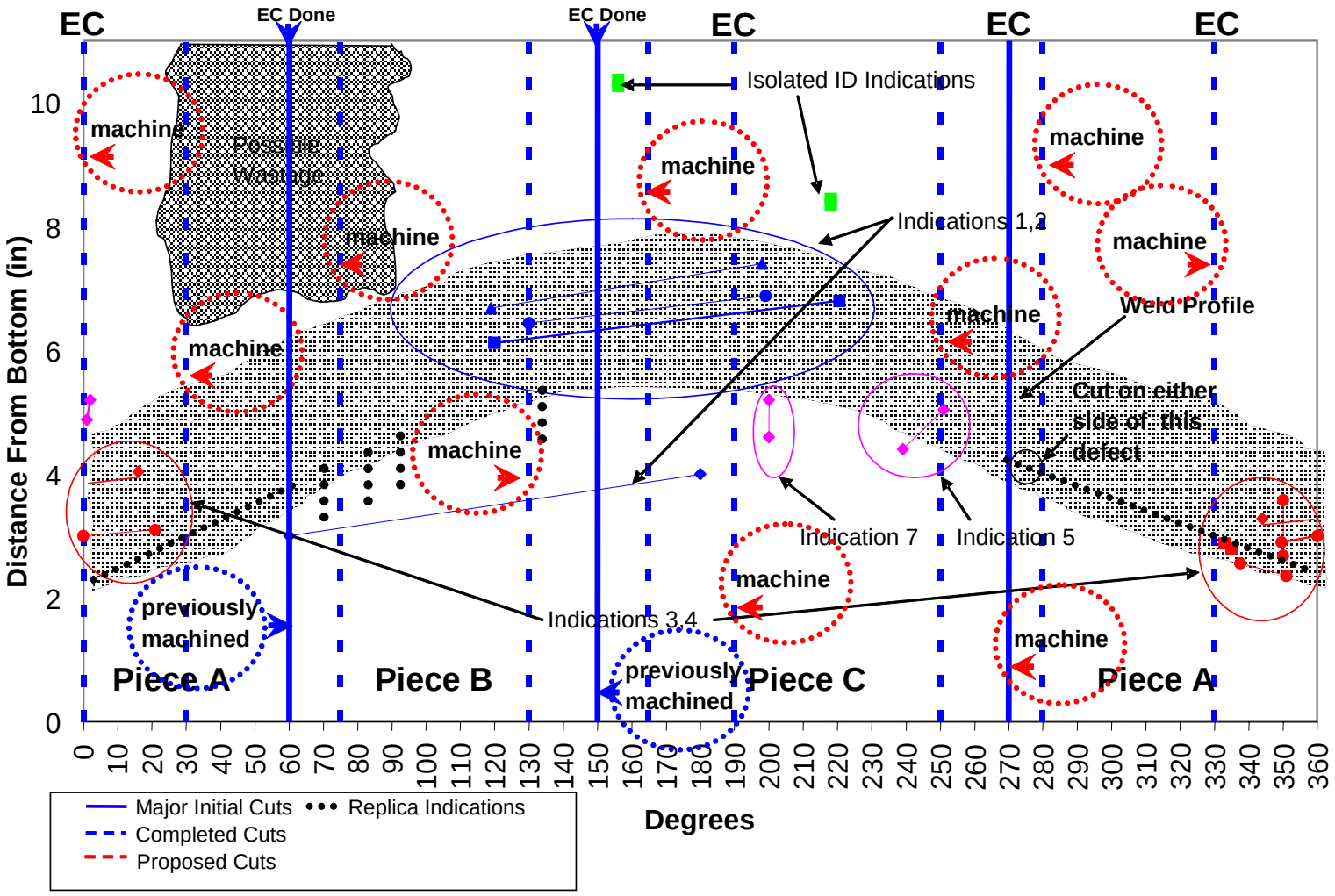
Subsequent Sectioning – Thinner Slices for More Detailed Examination

- Based on Eddy Current/Replication Results and Vendor Inspection Results
- Objective to Isolate Areas of Interest
- Plan is To
  - Section
  - Additional NDE on Faces
  - Prepare Locations for Examination
  - Detailed Investigation of Defects
- Same Slicing Process as “Rough Cutting”

Detailed Sectioning Plan



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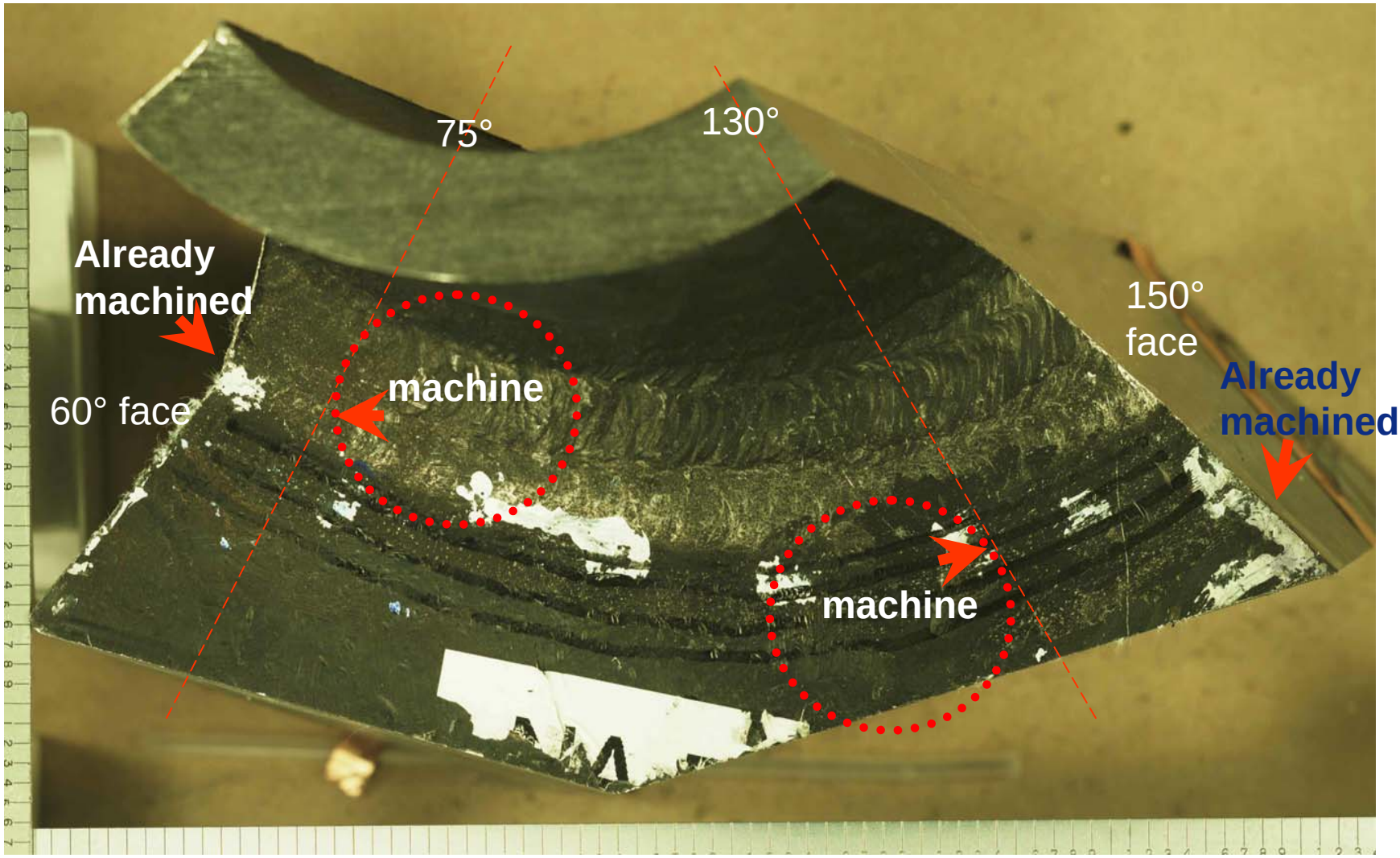
Piece B1A



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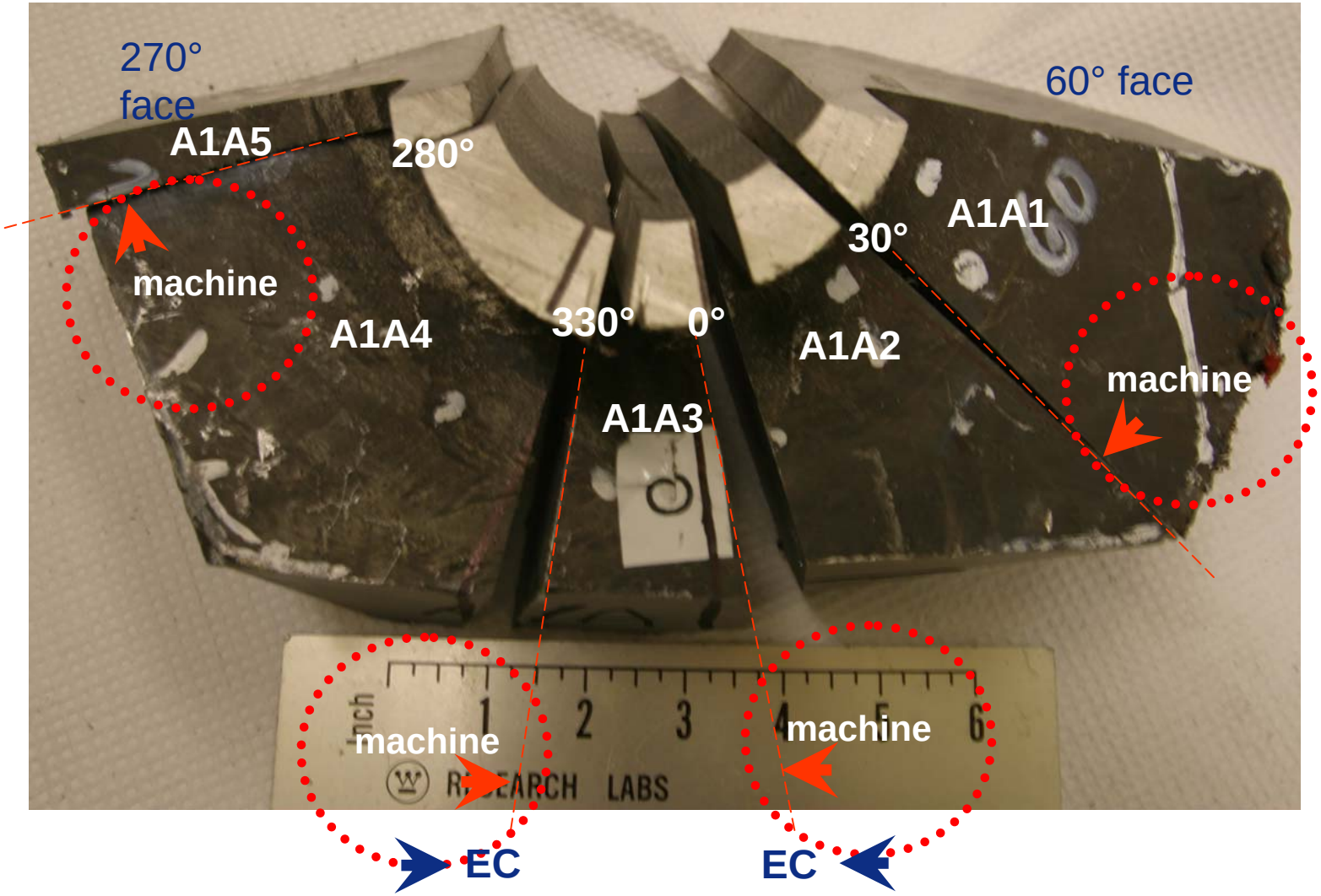
Piece A1A



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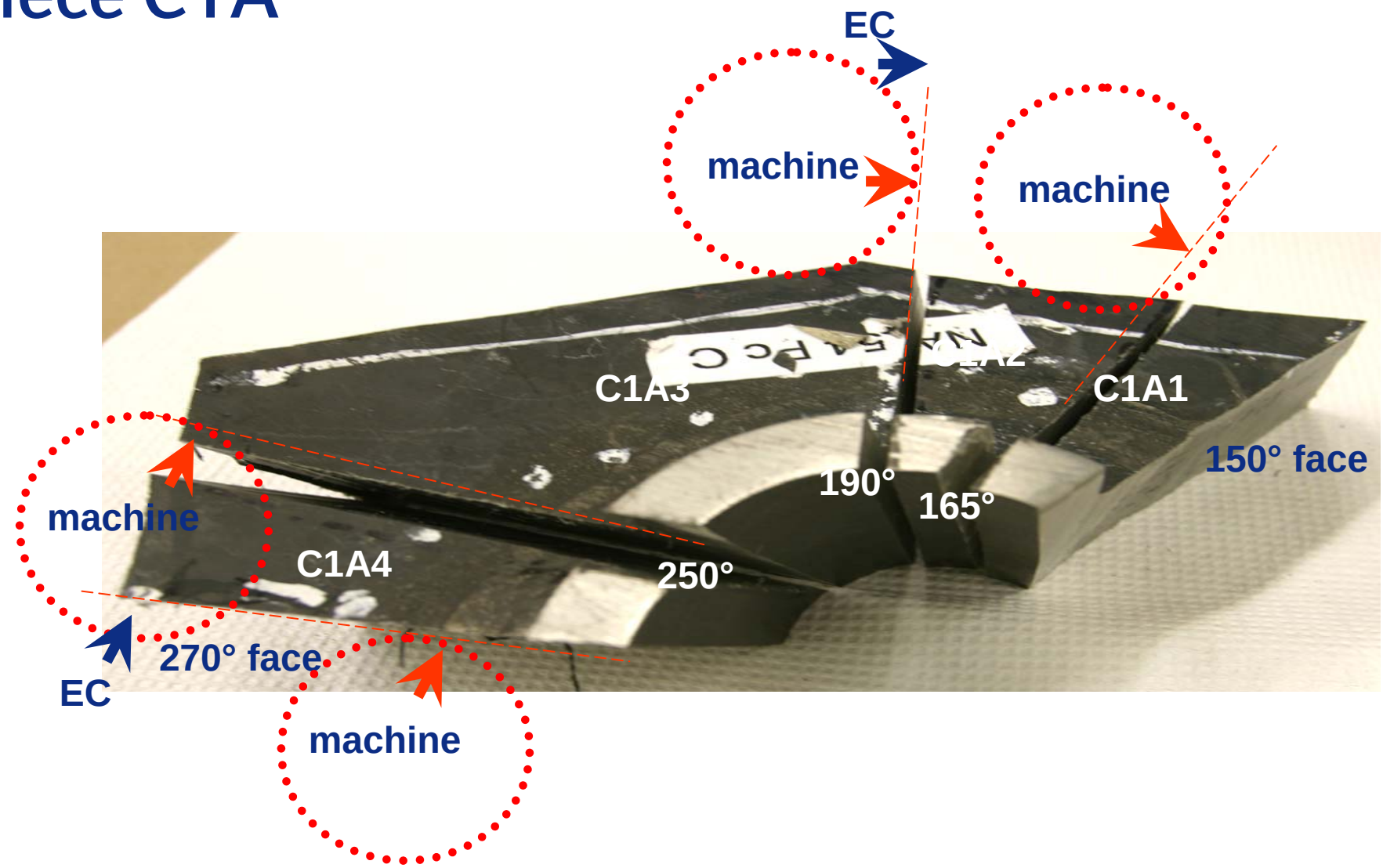
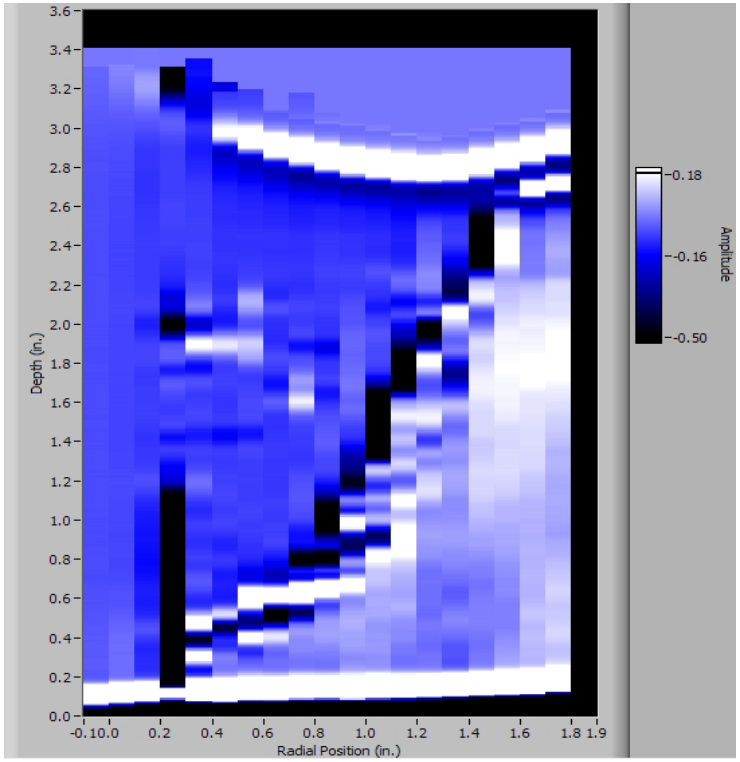
Piece C1A

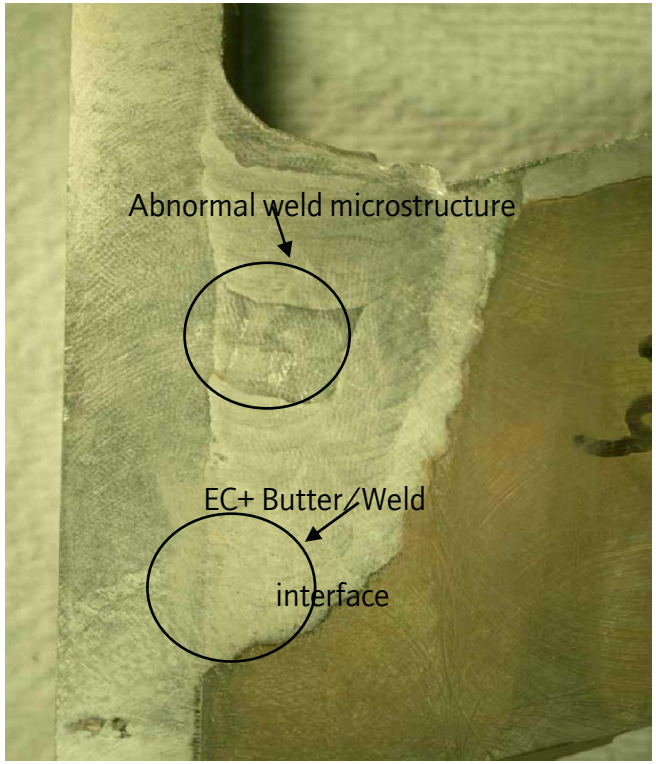

EC
machine
machine
C1A3
C1A1
150° face
190°
165°
machine
C1A4
250°
270° face
EC
machine

Eddy Current Examination of Sectioned Faces

- Use of + pt Eddy Current Tool to Examine Sectioned Faces
- Attempt to Identify Defects/Indications Prior to Metallographic Preparation
- Allows Identification of New Indications Missed by Original Section NDE
- Allows Metallographic Examination to Focus on Specific Areas
- Provide Continuing Observation and Tracking of Original NDE Indications through to Confirmatory Metallographic Observation
- "Guides the Eye" to Abnormal Weld Microstructure Regions
  - Butter/Weld Interfaces
  - Internal Weld Defects

Example of Eddy Current and Subsequent Metallographic Examination of Sectioned Face





Eddy Current Inspection Results for the 60 Deg. Face using the +Point Probe (Piece B1A5)
Abnormal Weld Microstructure and Weld Butter Interface

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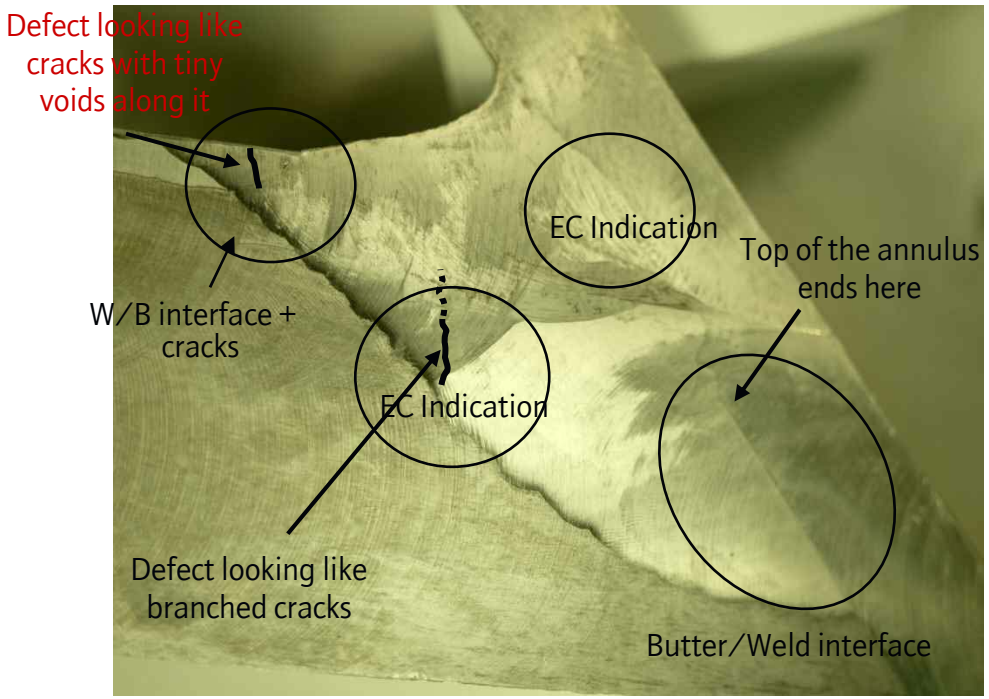
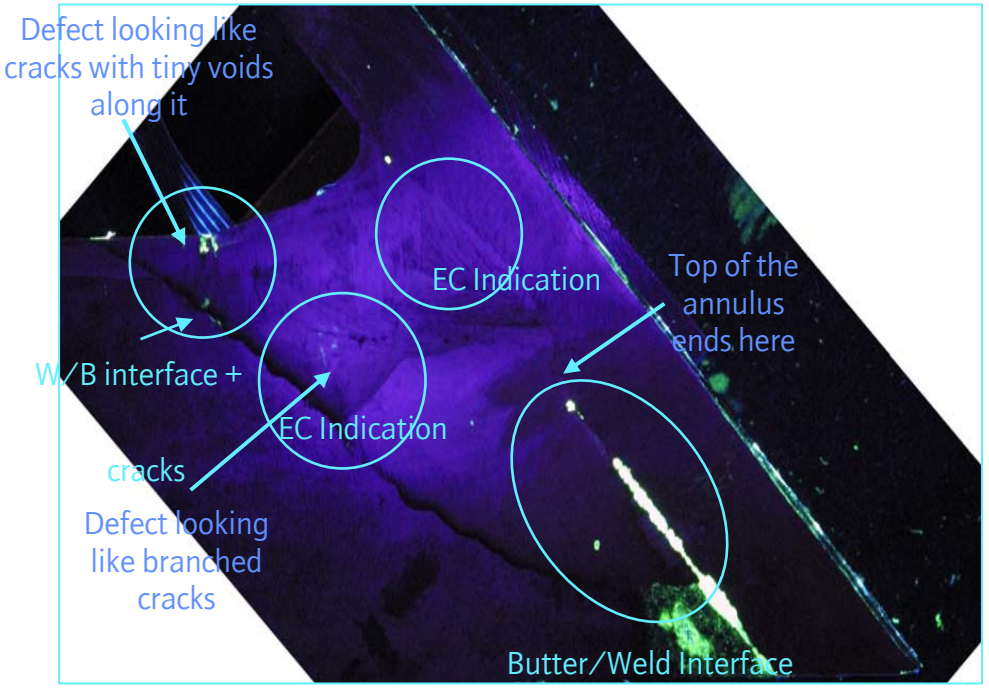
Correlation of Features in Metallography and NDE "Images"

- All Faces Examined (12 Azimuthal Sections)
- Allows Clarification of Defect Types from Different Views
  - + pt probe
  - Polished Section
  - Fluorescent Dye Penetrant
  - Etched Sections
- Weld Butter Interface are Visible in Ground Sections
- Weld Microstructure Visible in Several Sections
- Cracking Visible in Ground Sections – Clarified in Dye Penetrant Observations
- See Observations on 0 Degree Section (Piece A1A3)

Comparison of Optical Metallography and Dye Penetrant Images





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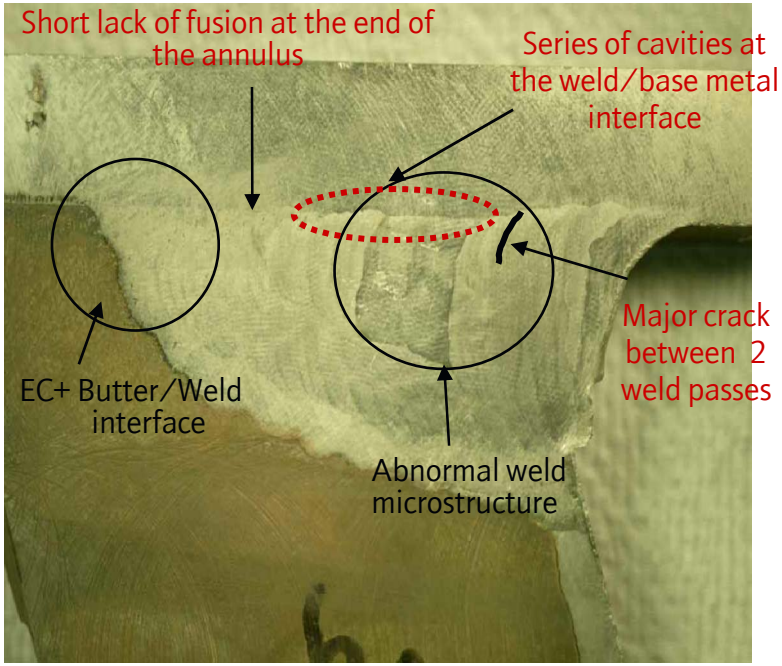
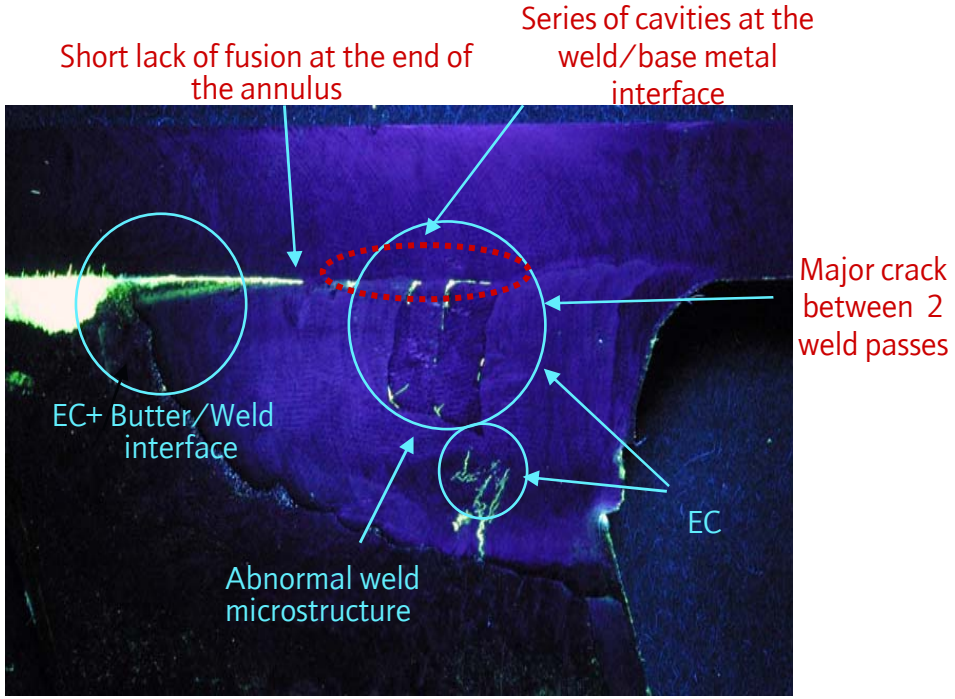
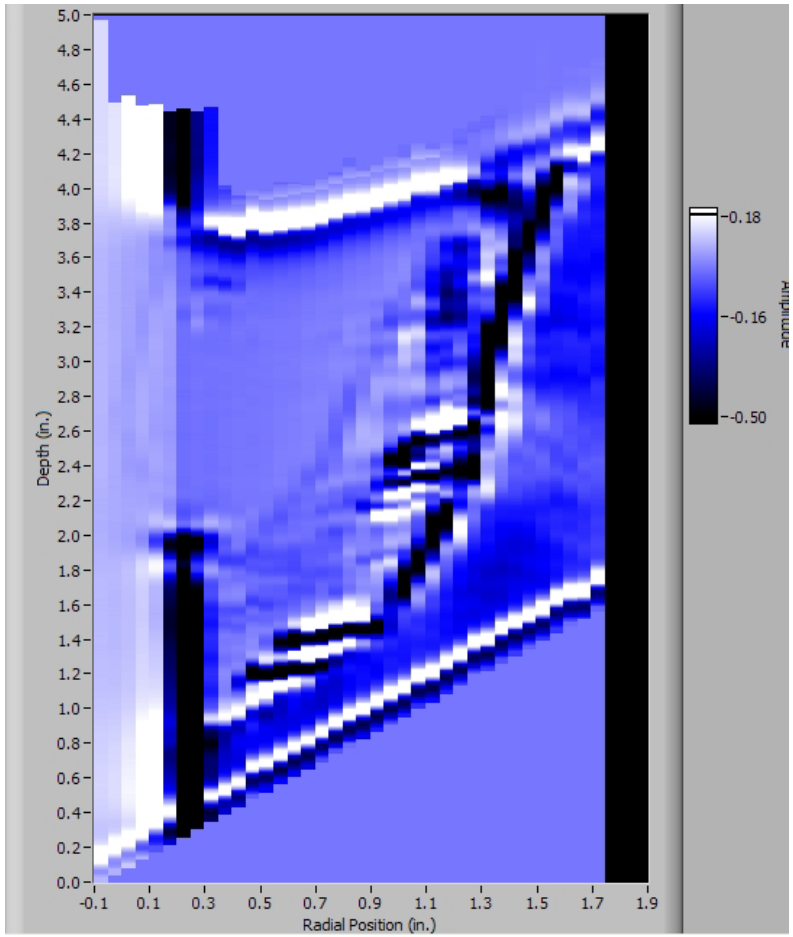
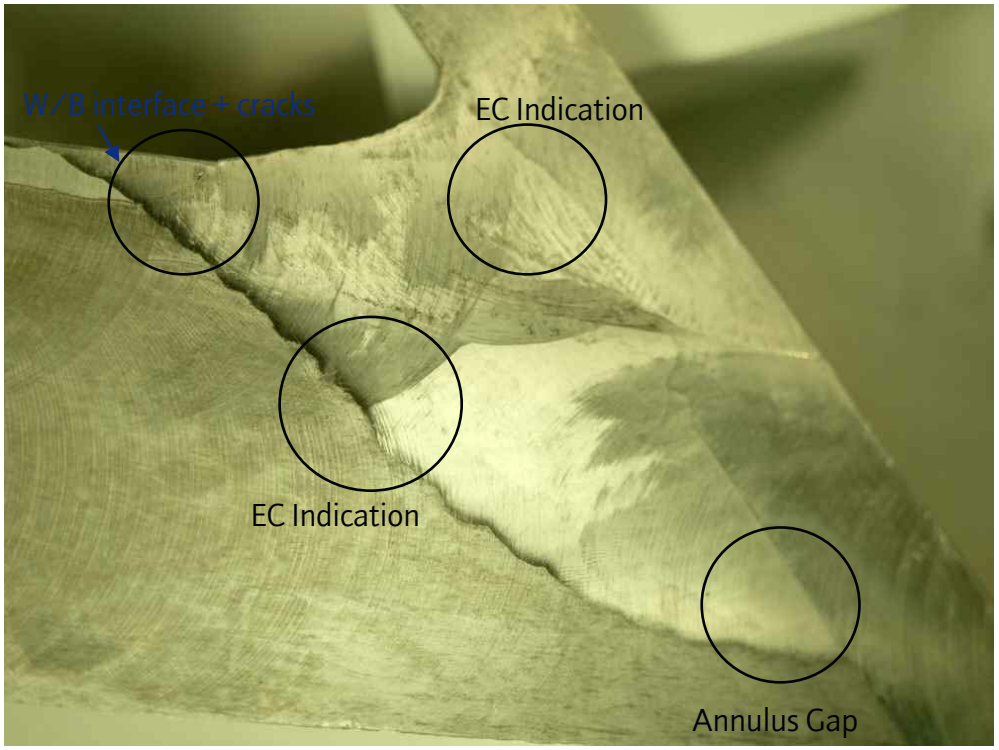




Eddy Current Inspection Results for the 0 Deg. Face Using the +Point Probe (Piece A1A3)





Finding of NDE and Low Magnification Metallographic Observations of Sectioned Faces

- Demarcation of Weld Butter Interfaces
- Regions of Abnormal Weld Microstructures
  - Regions of Weld Repair/Overlay
- Cracks in Welds, Branched Cracks, Crack Networks
- Void Alignment on Cracking/Series of Cavities
- Lack of Fusion Regions (Including at the End of Annulus)
  - Pursue Detailed Examination of Key Factors

Summary of Approach and Findings to Date

- Removal of Excess Carbon Steel is Necessary and Time and Resource Consuming
- Vendor NDE is a Good Starting Point but must be Supplimented by Lab. NDE and Replication
- Replication was most Useful at Confirming Weld Defect Locations and Help Minimize Personnel Radiation Exposure
- Replication was Helpful in Identifying Surface Cracks

Summary of Approach and Findings to Date (cont.)

- 3-D Model Aids Visualization of Defect Locations Facilitates Development of Sectioning Plan
- Sectioning Procedures Employed Rigid Clamping and Simple Tooling Developed by Westinghouse Hot Cell Technicians
- Use of NDE Methods on Sectioned Slices Provides an Innovative Way to Track Indications and to Properly Locate (Old and New) Defects